X-400-66-440

NASA TM X-55754

SPACE ADAPTED STEP-SERVO ASSEMBLY ENVIRONMENTAL TESTS

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SEPTEMBER 1966

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ENVIRONMENTAL TESTS

GENERAL

The NRL, OSO-D X-Ray and Lyman-Alpha experiments each contain a servo-motor-pot assembly whose function is to position a disc in one of several pre-selected positions.

In both experiments the discs serve as range-changing mechanisms in that they contain various sized openings that control the amount of radiation that is allowed to enter the X-ray or Lyman-Alpha detectors.

The experiments will be required to operate in an outer space environment of 10^{-7} mm Hg for a period of six months. The servo assembly will be controlled by ground command signals when range-changing is desired. Except when commanded, the servo assembly will not be energized.

DESCRIPTION OF STEP-SERVO ASSEMBLY

The Step-Servo Driven Potentiometer Assembly[1] unit consists of an inline mounted step-servo motor and gearhead and an integral mounted three-turn potentiometer. See Figure 1. The control accuracy at the pot position is 2°.

The motor is a size 8 stepping motor which advances 90° for each input pulse. It has 2 quadrant windings, each having 900 ohms resistance. The stated operating temperature range is -55 to +125°C. The motor is coupled to the 50K three turn pot[2] through a 45 to 1 gear reducer. A protruding shaft from the pot mounts a drive gear that rotates the disc by engaging the rim teeth along its circumference.

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[1]Part No. 891 - Model No. 783-8-900-125. Manufactured by the Automation Development Corp., Monterey Park, California.

[2]Model No. 1201. Manufactured by Duncan Electronics, Santa Ana, California.

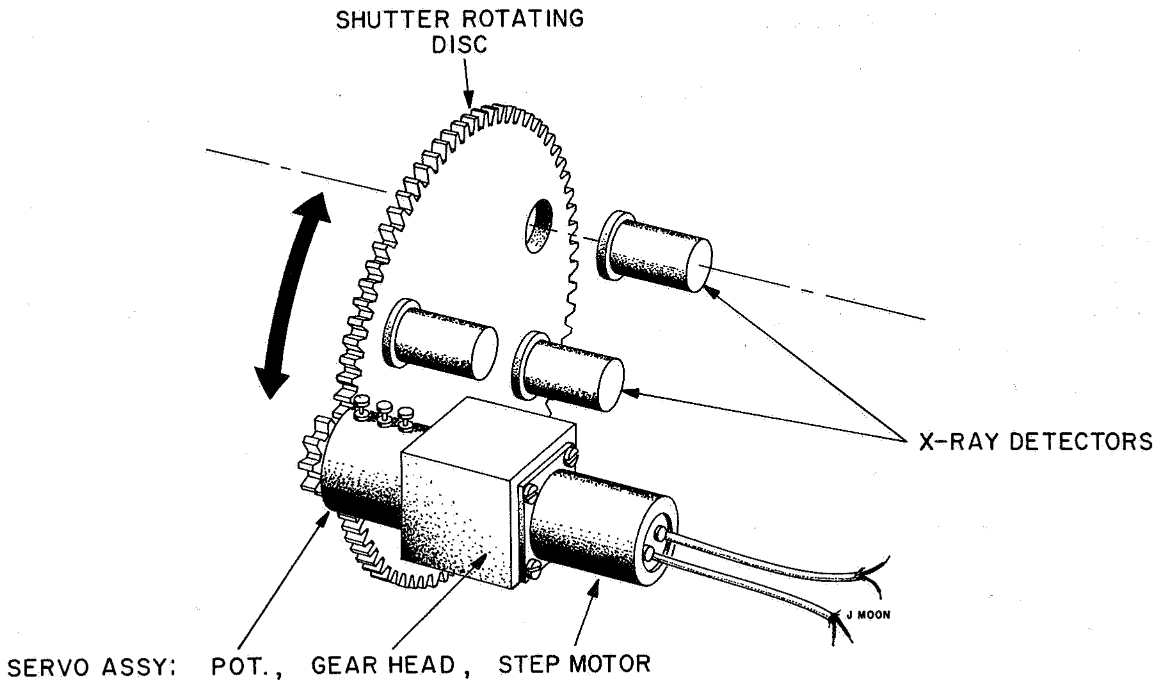


Figure 1

PURPOSE OF TEST

It was decided to conduct an environmental test on the servo-pot assembly since little or no definite specifications were available as to expected life in a space environment that we expected.

As explained later under Systems Operation, preliminary information on the potentiometer part of the assembly indicated that it would have a life of only 10 or 20 commands. If true, this would of course have been completely unsatisfactory.

The step-motor and gear head were not assumed to be very doubtful since similar ones had worked satisfactorily in other space experiments according to the manufacturer. Never-the-less they were also tested since they were an integral part of the assembly.

SYSTEM OPERATION

In actual operation the step-servo system will position the aperture disc at one of three positions, 0° and ±30°.

These positions are selected by an appropriate ground command.

On receiving a ground command the servo assembly rotates the disc to the desired position and then "hunts" at this spot for several seconds.

A 20-second timer is initiated on receipt of a ground command. This timer applies power to the servo assembly and control circuitry for a period of 20 seconds and is used to conserve power. During this 20 second period the servo assembly must rotate the disc to the desired position. Under normal conditions it requires six seconds for the disc to reach an adjacent position. Twelve seconds would be required to travel from one extreme position to another. Once the disc attains the desired position, the servo system will "hunt" until the 20 second period terminates. "Hunting" therefore, will normally last for 8 or 14 seconds depending on the initial position of the disc and the "commanded" position.

The "hunting" period is a safety factor to take care of any tolerance changes that might otherwise prematurely stop the servo action before the disc has reached the desired position. Hunting of course will have an abnormal effect on the potentiometer in that it will greatly increase the wear on the windings at the three selected positions.

It should be born in mind that the pot wiper travel during "hunting" is very small, therefore only a few strands of the pot winding are traversed thus aggravating the problem.

The stepping-motor in the assembly operates at approximately 40 pulses per second. If the hunting period is 8 seconds this means the potentiometer winding will be wiped approximately 320 times each time a command is sent. For a 14 second hunting period this increases to 560 wipes per command.

Preliminary specs on the potentiometer indicated a space environment life of only 5000 cycles. If this were true, only 10 to 20 commands could be sent before the potentiometer would be expected to fail. This of course would be intolerable.

Because of this fact it was decided to perform an accelerated life test under simulated environmental conditions to determine time-till-failure of the entire servo-pot assembly.

TEST SET-UP

Figure 2 is a block diagram of the test set-up. The servo-pot assembly only was placed inside the vacuum chamber. All other equipment was external.

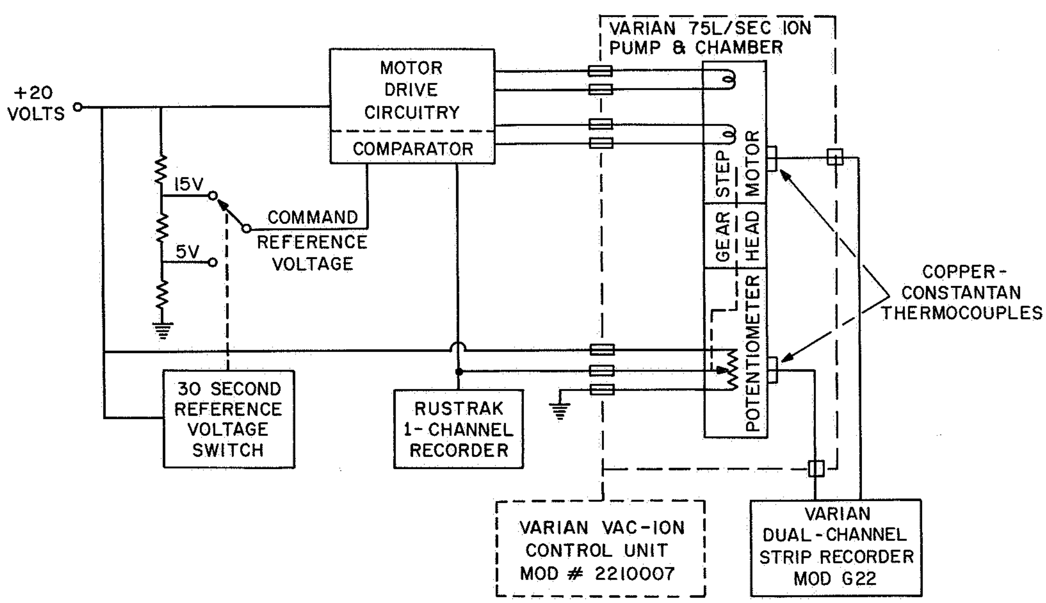
Copper-Constantan thermocouples were attached to the housings of the step motor and the potentiometer to monitor temperature. These thermocouple leads were brought out to a two-channel strip recorder.

The wiper arm voltage of the potentiometer was attached to a single channel recorder as shown. A D.C. power supply furnished the +20 volts that was needed to operate the electronics portion of the set-up.

The vacuum system and controls are as noted in Figure 1.

TEST PROCEDURE

The step-servo assembly was placed inside the vacuum chamber, Figure 2, and placed under the maximum vacuum possible with the Vac-Ion system used.



BLOCK DIAGRAM OF SERVO ASSEMBLY ENVIRONMENTAL TEST SET-UP

Figure 2

A 30 second Reference Voltage Switch simulated ground command signals. Every 30 seconds the relay in the unit operates a two pole switch that applies one of two command reference voltages, +5V or +15V, to the system.

The step-servo system then positioned the potentiometer such that its output voltage equalled the command reference voltage for that interval. In essence this is a two-command system with the potentiometer assuming one of two positions which correspond to ±15° positions of the driven disc. It will be remembered that in actual operation the disc, and therefore the pot, can assume three positions. On receiving a command signal the servo system requires approximately 7 seconds to reach the required position. The system then hunts the remaining 23 seconds before the next command. In actual operation, hunting lasts only 8 or 12 seconds. See System Operation.

In general the servo-system was operated only during the normal 8-hour work day. On several occasions however, the tests were run continuously for longer periods. The maximum continuous operating time was about 100 hours.

Thermocouples were attached to the step motor and potentiometer housings and the temperature readings recorded on a dual-channel strip recorder.

The output voltage of the potentiometer was recorded on a one channel recorder. This voltage was used as an index of proper system operation. If the recorded levels corresponded to the two command reference voltages, 5V and 15V, it was assumed the system was functioning properly.

Pressures were recorded each time the servo system was turned on and off.

TEST RESULTS

Table 1 shows the data for the complete test. The servo-assembly was under continuous vacuum for a period of 12 weeks before it failed. During this time it was operated for a total of about 531 hours.

Approximately 60,000 commands were received by the assembly before it failed. The cause of failure was an open circuit in the potentiometer winding. The break occurred at one of the selected (commanded) potentiometer positions. See Fig. 3.

The maximum motor temperature attained was 58°C. Maximum potentiometer temperature was 40°C. The average pressure was approximately 2×10^{-7} mm Hg.

Table 1

OSO-D Motor-Gearbox-Potentiometer Life Test.

Date	Time Start	Time Stop	Time Operated (Min.)	Pressure Start (mm Hg.)	Pressure Stop (mm Hg.)	Motor Temp. Start °C	Pot. Temp. Start °C	Motor Temp. Stop °C	Pot. Temp. Stop °C
11/17/65							25	58	37
11/18								58	38
11/19	1018	1645	387	1.5×10^{-7}	4×10^{-7}	27	25	57	38
11/22	0850	1627	457	1×10^{-7}	4×10^{-7}	26	24	55	36
11/23	0800	1653	533	8×10^{-8}	4×10^{-7}	26	25	54	36
11/24	0800	1608	488	8×10^{-8}	3×10^{-7}	26	26	54	36
11/29	0914	1625	431	3×10^{-8}	1×10^{-7}	25	25	54	36
11/30	0836	1700	504	6×10^{-8}	2×10^{-7}	26	28	54	37
12/1	0850			6×10^{-8}		27	28		
12/2		1150	1620		2×10^{-7}			54	36
12/6	0926	1718	472	5×10^{-8}	1.5×10^{-7}	27	29	54	36
12/7	0940	1701	441	5×10^{-8}	1.4×10^{-7}	27	28	54	37
12/8	0839	1700	501	4×10^{-8}	1.4×10^{-7}	28	26	53	37
12/9	0832	1700	508	4×10^{-8}	1.4×10^{-7}	29	30	54	38
12/10	0900	1650	470	4×10^{-8}	1.4×10^{-7}	29	29	54	40
12/13	0834	1655	501	4×10^{-8}	1.2×10^{-7}	29	30	53	38
12/14	0833	1645	492	3.8×10^{-8}	1.1×10^{-7}	29	31	53	39
12/15	0836	1655	499	3.8×10^{-8}	9×10^{-8}	29	28	53	39
12/16	0851	1700	489	3.8×10^{-8}	1×10^{-7}	29	28	52	39
12/17	0840	1620	460	3.8×10^{-8}	1×10^{-7}	29	31	53	39
12/20	0855			3.5×10^{-8}		28	30		
12/21		1615	1880		8×10^{-8}			54	39
1/5/66	0900	1630	450	3×10^{-8}	7.8×10^{-8}	27	30	53	40
1/6	0850	1650	480	3×10^{-8}	6×10^{-8}	28	31	53	37
1/7	0840	1615	455	2.5×10^{-8}	3×10^{-7} *	27	29	53	37
1/10	0840			8×10^{-8}		27	30		
1/12		0836	2876		3×10^{-7}			53	37
1/8	1100			8×10^{-8}		28	30		
1/21		1607	4627		2×10^{-7}			51	36
1/25	0915			4×10^{-8}		25	28		
1/28		1630	4755		2×10^{-7}			50	37
1/31	0850			4×10^{-8}		25	28		
2/4		1650	6240		2×10^{-7}			50	37
2/7	0840	1100	140	4×10^{-8}	2×10^{-7}	25	28	50	37

Total Time Operated: 3806 Min. Avg. Press. = 2×10^{-7} mm

Pot. Failed (Opened) at ~ 0900, 2/7/66.

*Pressure gage recalibrated

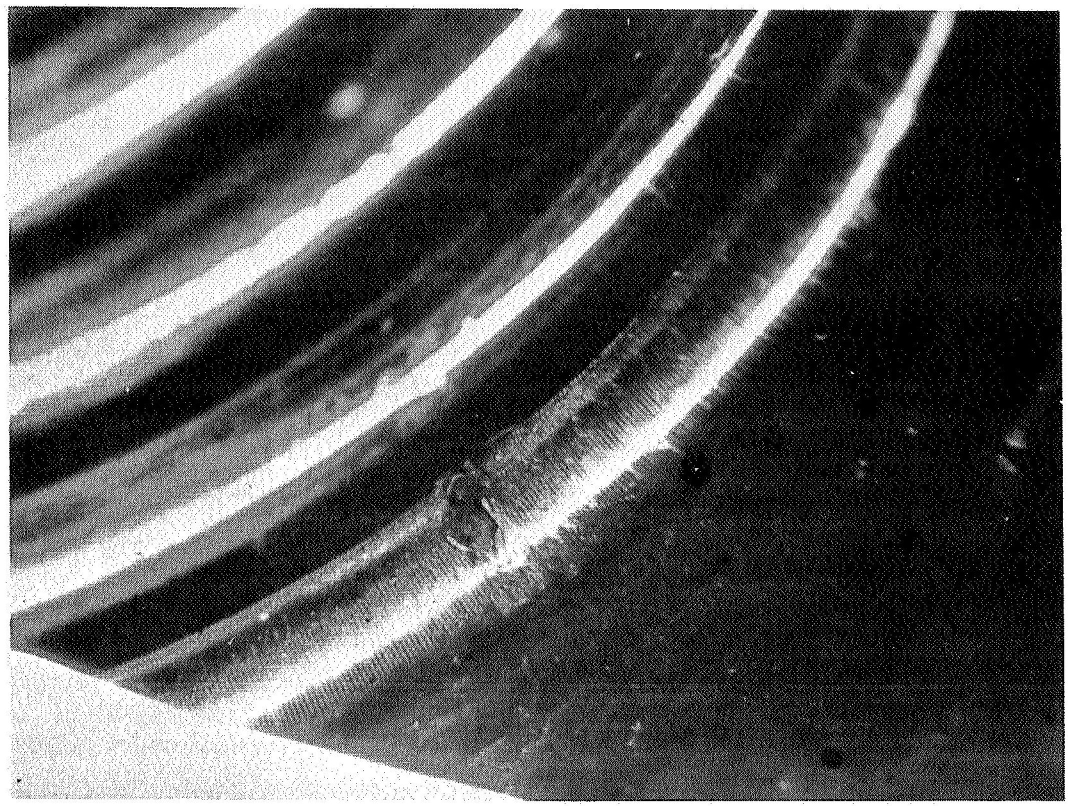


Figure 3

DISCUSSION OF TEST RESULTS

Assuming a maximum of three commands per orbit (1-1/2 hrs.) a total of approximately 3000 would be sent in a six months period. A total of over 60,000 commands were sent during the test.

This would indicate that the servo unit should last 20 times the desired experiment life or 10 years. Actually, the time-before-failure, indicated by this test is conservative since three important factors have been ignored:

1. In actual flight the potentiometer can assume three different positions whereas in the test only two positions were used.

2. "Hunting" action will last on an average about 10 seconds for each ground command sent during flight. For this test the hunting period was approximately 23 seconds.

3. It is anticipated that the maximum command rate will be about three per hour. The command rate for the test was one per 30 seconds or 120 per hour.

Considering only fact 1, it seems logical to assume that the life of the potentiometer will be reduced by a factor of one third if only two positions are used. This means that the pot life will be 50% greater than indicated by the test.

Considering only fact 2, since the "hunting" period for the test is greater than twice that expected, the life of the potentiometer should be at least twice the life indicated by this test.

Combining these two facts therefore, the potentiometer life would be expected to be at least 2-1/2 times that indicated by the test.

Fact 3 is difficult to evaluate. It would be safe to say however, that the high command rate would tend to cause more severe heating and therefore degrade the servo unit more rapidly.

It would seem reasonable to assume therefore, that the life of the servo unit is at least twice that indicated by this test.

The potentiometer, as expected, was the weak link in the assembly. Failure occurred due to abrasion of the winding by the wiper during the hunting interval.

No over-heating problem was detected. The maximum motor and potentiometer temperatures were well within reasonable limits.

CONCLUSIONS

The test results indicate that the step-servo assembly should operate satisfactorily for the minimum expected six-months duration of the X-Ray and Lyman Alpha OSO-D satellite experiments.

Actually the assembly should last quite a bit longer, perhaps two or three years, should the satellite and experiments function for that length of time.

If the potentiometer could be improved, the lifetime of the assembly would probably increase proportionally.

ACKNOWLEDGMENTS

The test work was done at Goddard Space Flight Center, Greenbelt, Maryland by the Structural and Mechanical Applications Section of the Spacecraft Integration and Sounding Rocket Division. The Section Supervisor was Mr. Francis LeDoux. G.S.F.C. personnel involved in the tests were Mr. Frank Fash and Mr. Robert H. Peterson. Mr. Ray Wilkinson, NRL, designed and constructed the electronic test circuitry and did the liaison work.